



Search for Excited/Exotic Electrons at CDF in Run II

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PHENO SYMPOSIUM 2004**

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- ▶ **Excited/Exotic Electron Models**
- ▶ **Model Acceptances**
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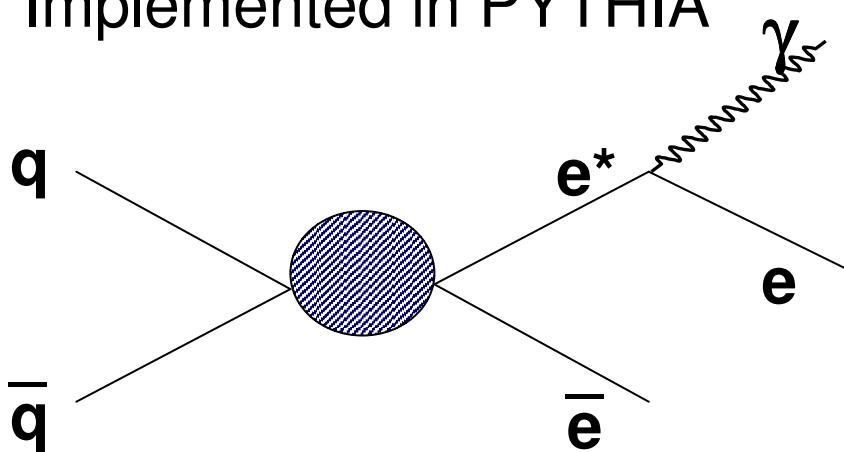
Introduction/Motivation

- ▶ The hierarchical structure of the standard model families could be indication of quark and lepton substructure
- ▶ The observation of excited states of leptons or quarks would be a first indication of their compositeness
- ▶ We search for singly produced excited/exotic electrons in association with a positron, where the excited electron decays in the electron + photon channel
- ▶ $p\bar{p} \rightarrow e^* + \bar{e} \rightarrow e\gamma + \bar{e}$

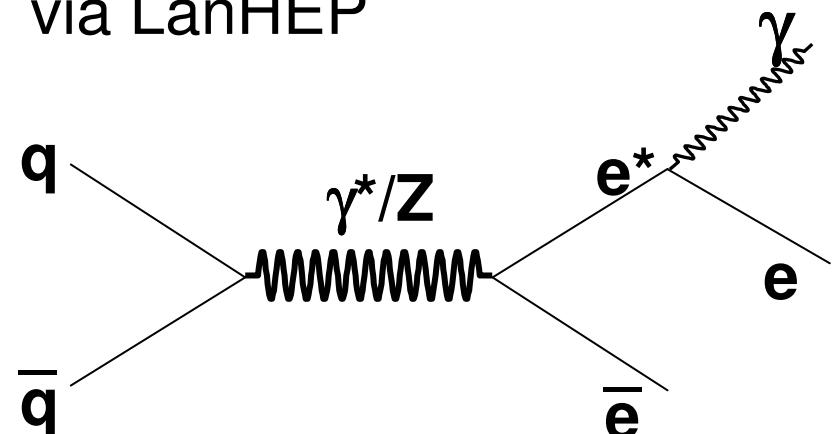


e* Models

- ▶ Contact Interaction Model
- ▶ (U. Baur, et.al., Phys Rev D. V42,3)
- ▶ Effective four-fermion Lagrangian
- ▶ Model depends on M_{e^*} and Λ (Compositeness Scale)
- ▶ Implemented in PYTHIA

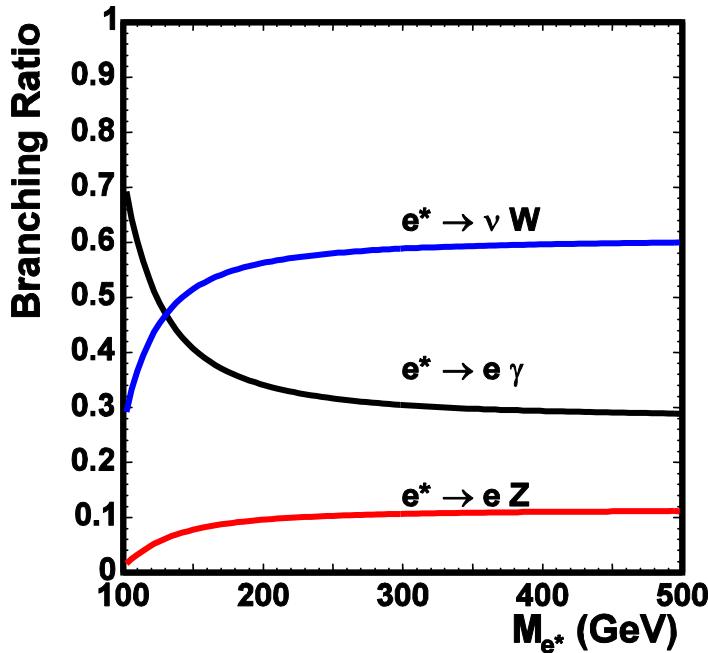


- ▶ Gauge Mediated Model
- ▶ (K. Hagiwara, et. al., Z.Phys. C29:115, 1985)
- ▶ Model depends on M_{e^*} and f/Λ
- ▶ Implemented in CompHEP via LanHEP



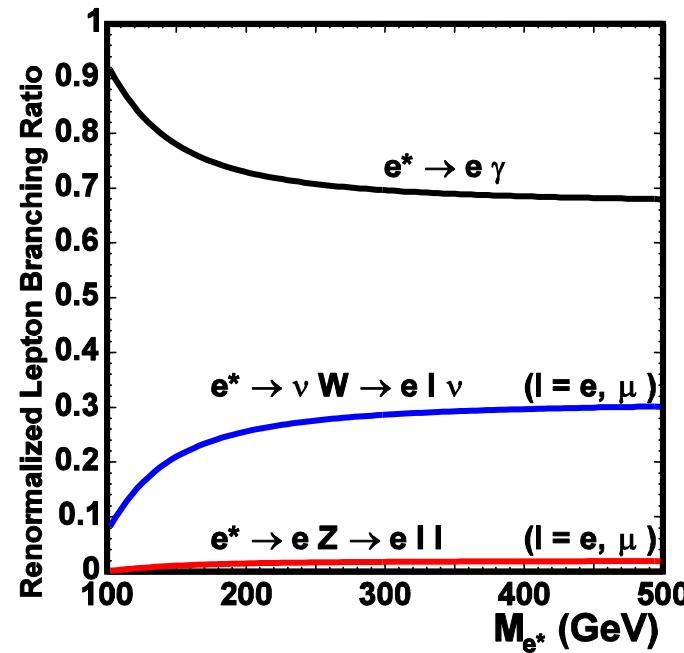
e^* Decay Channels

- ▶ There are three decay channels:
 - $e^* \rightarrow e\gamma$
 - $e^* \rightarrow eZ$
 - $e^* \rightarrow \nu W$



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- ▶ Force the Z and W to decay leptonically
 - Very clean signal
 - Low Background
 - Good Energy Resolution
- ▶ Renormalized Branching Ratio
- ▶ $e^* \rightarrow e\gamma$ is the chosen channel

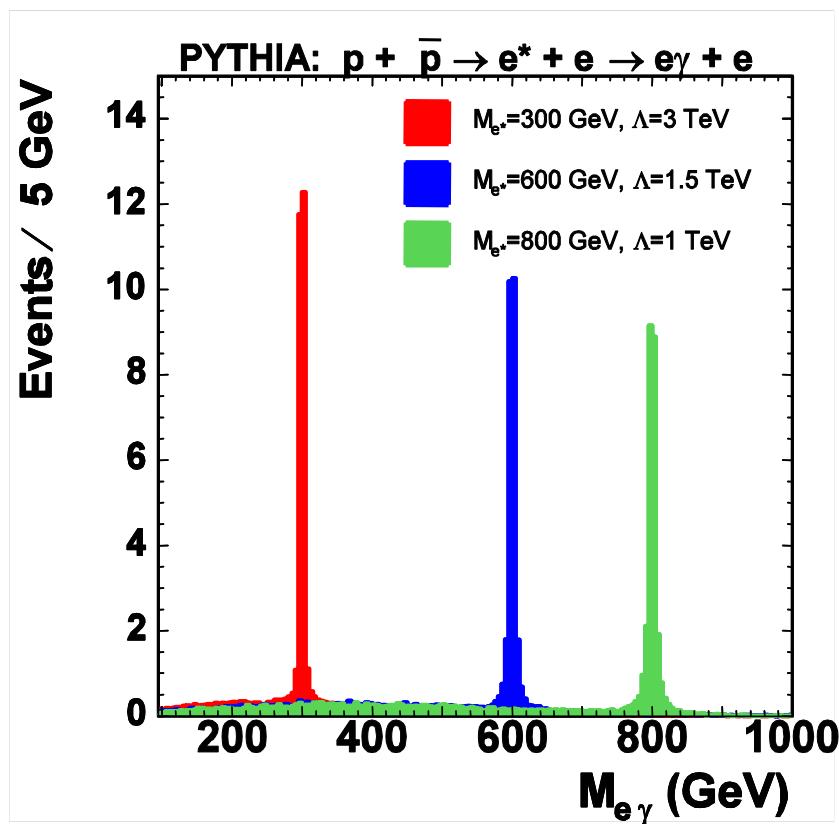


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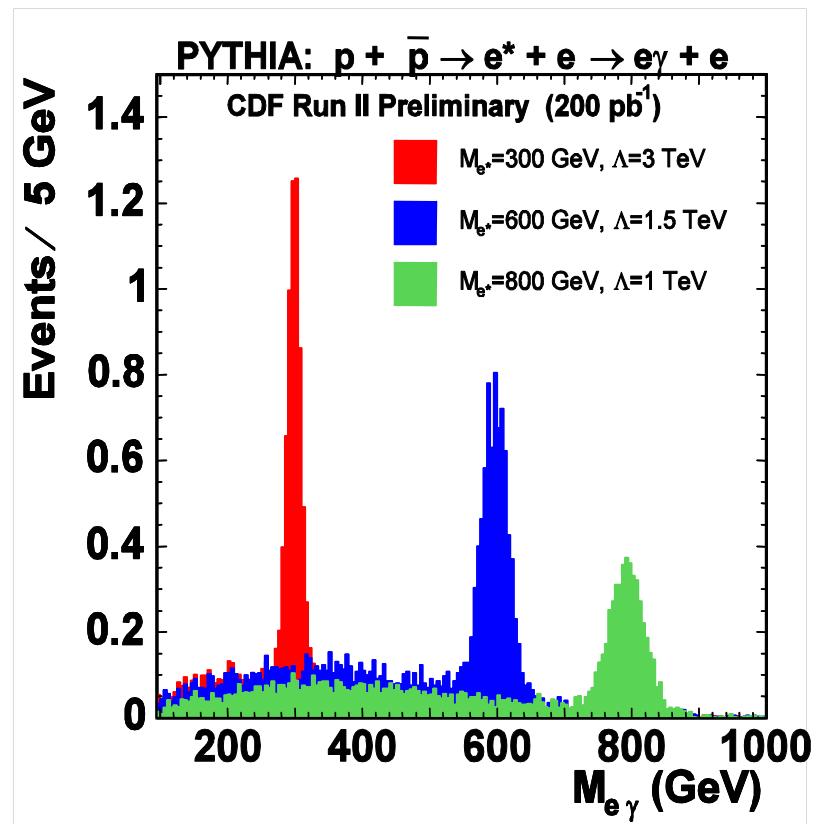


$e^* \rightarrow e\gamma$ Decay Channel

- ▶ $\Gamma_{th} \propto M_{e^*}^3 / \Lambda^2$: for $M_{e^*} < \Lambda$, an e^* signal would manifest itself as a narrow resonance peak in the $e\gamma$ invariant mass
- ▶ The width is dominated by detector energy resolution



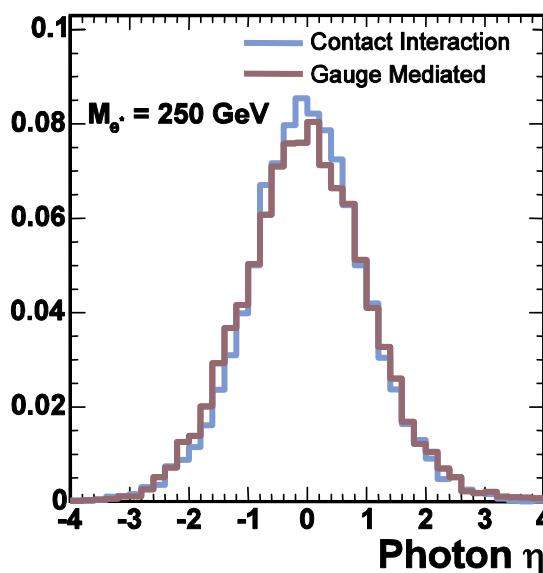
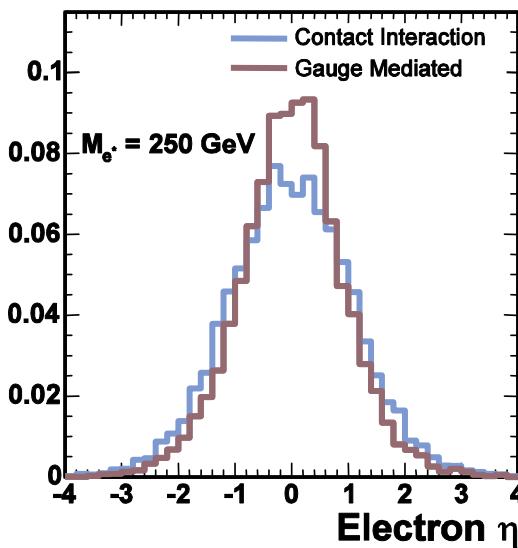
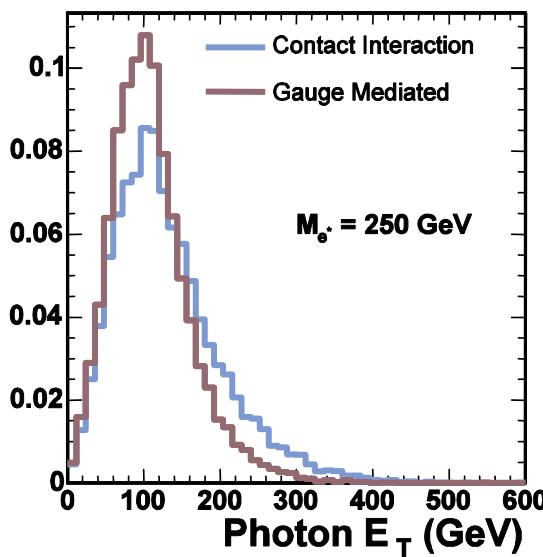
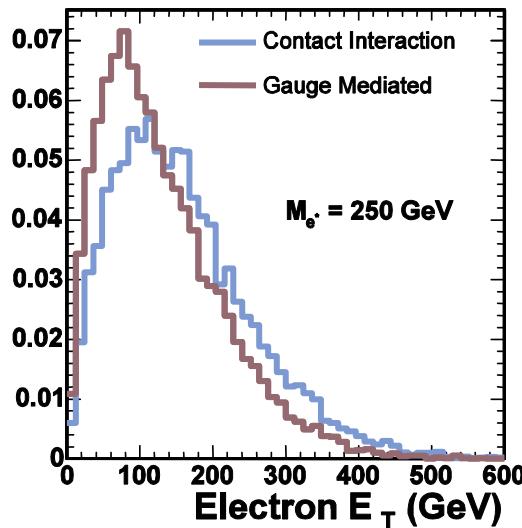
- Parton Level



- After CDF Simulation



E_T and η Distributions

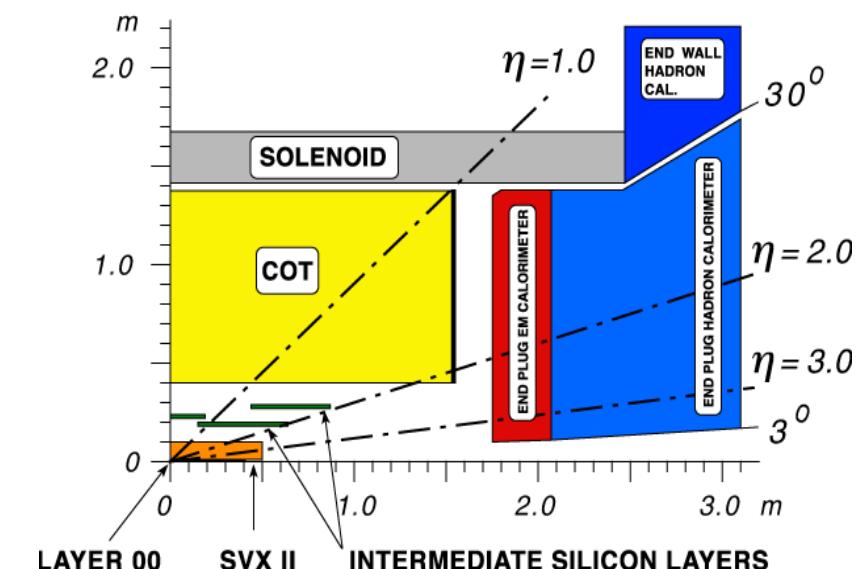
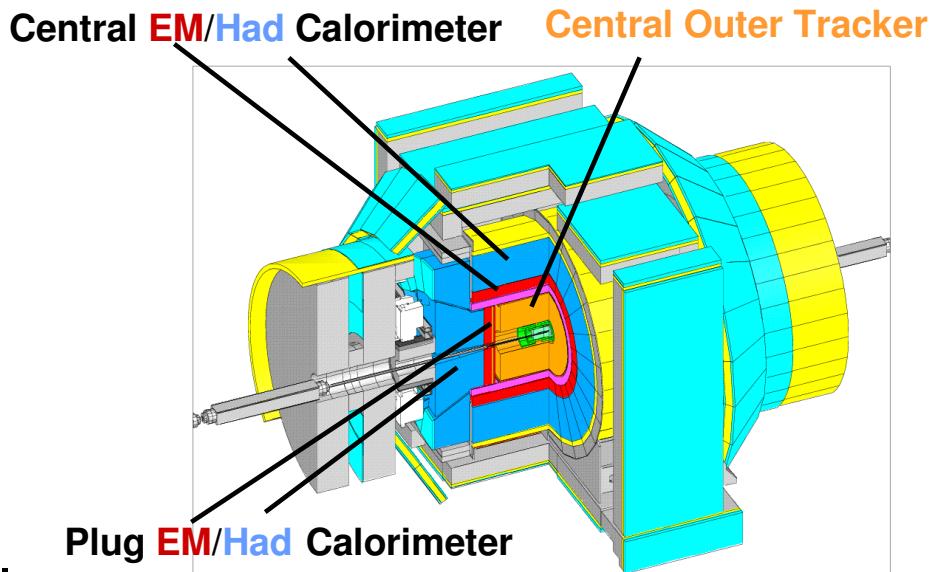


- ▶ Parton level E_T and η distributions for the electron produced in association with the excited electron and the photon from the excited electron decay for $M_{e^*}=250$ GeV
- ▶ Kinematics are different so we measure acceptances for both models
- ▶ Areas normalized to 1



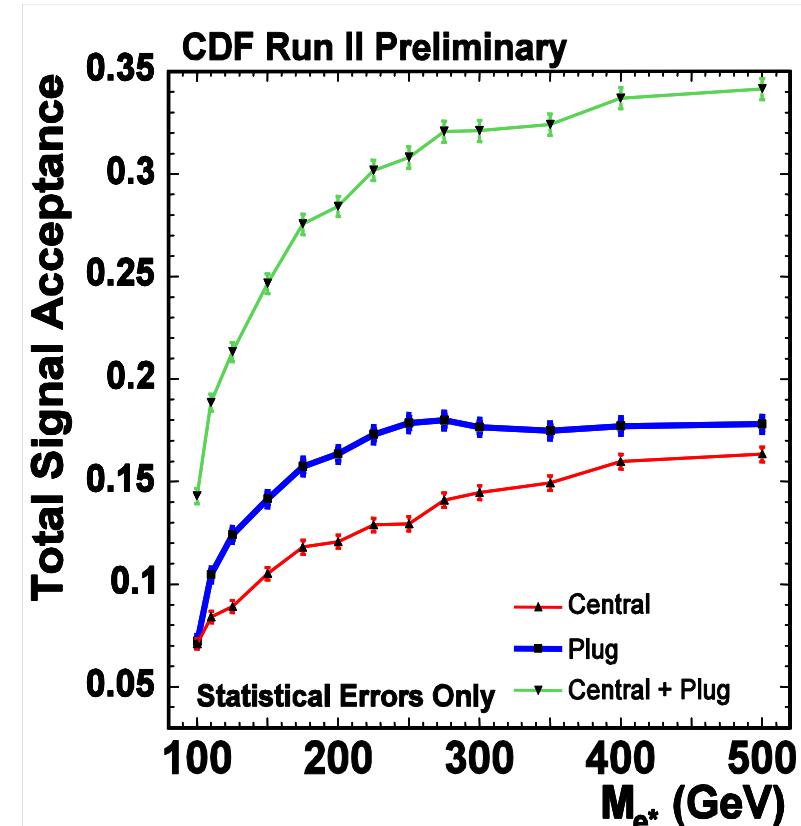
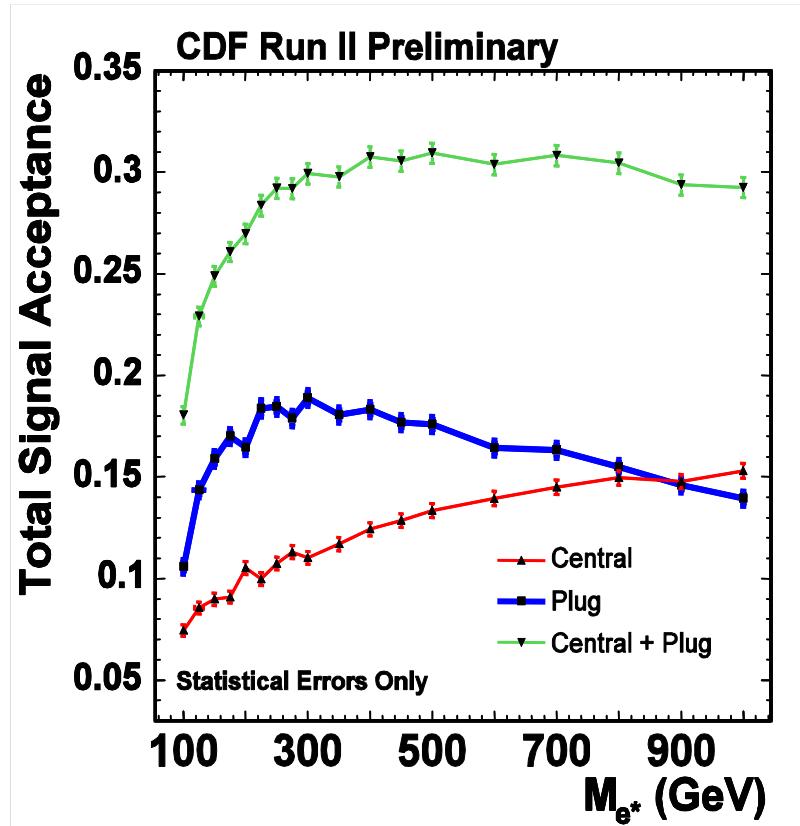
CDF Detector and Event Selection

- ▶ $\int L \cdot dt = 200 \text{ pb}^{-1}$
- ▶ High E_T electron trigger
- ▶ Search for two electrons and one photon, where one electron must be central
- ▶ Track requirements in central region, none in plug
- ▶ To reduce background due to $Z\gamma$ and $Z+jets$, we reject events with dielectron invariant mass in the Z mass range (81-101 GeV)





Total Signal Acceptance



- Contact Interaction Model
- The new Run II plug detector increases the acceptance by more than a factor of 2
- Gauge Mediated Model



Dielectron + Photon Backgrounds

► Standard Model:

- $Z/\gamma^* + \gamma \rightarrow ee + \gamma$
- $W(\rightarrow e\nu)Z(\rightarrow ee)$ (where electron is misidentified as a photon)
- $Z(\rightarrow ee)Z(\rightarrow ee)$ (where electron is misidentified as a photon)
- $t\bar{t} \rightarrow e^+\nu b + e^-\bar{\nu} b$, where the b radiates a hard γ

► Jet Misidentification Backgrounds:

- $Z(\rightarrow ee) + \text{jet}$
- Multi-jet
- $\gamma\gamma + \text{jet}$
- $W(\rightarrow e\nu) + \text{jet}$

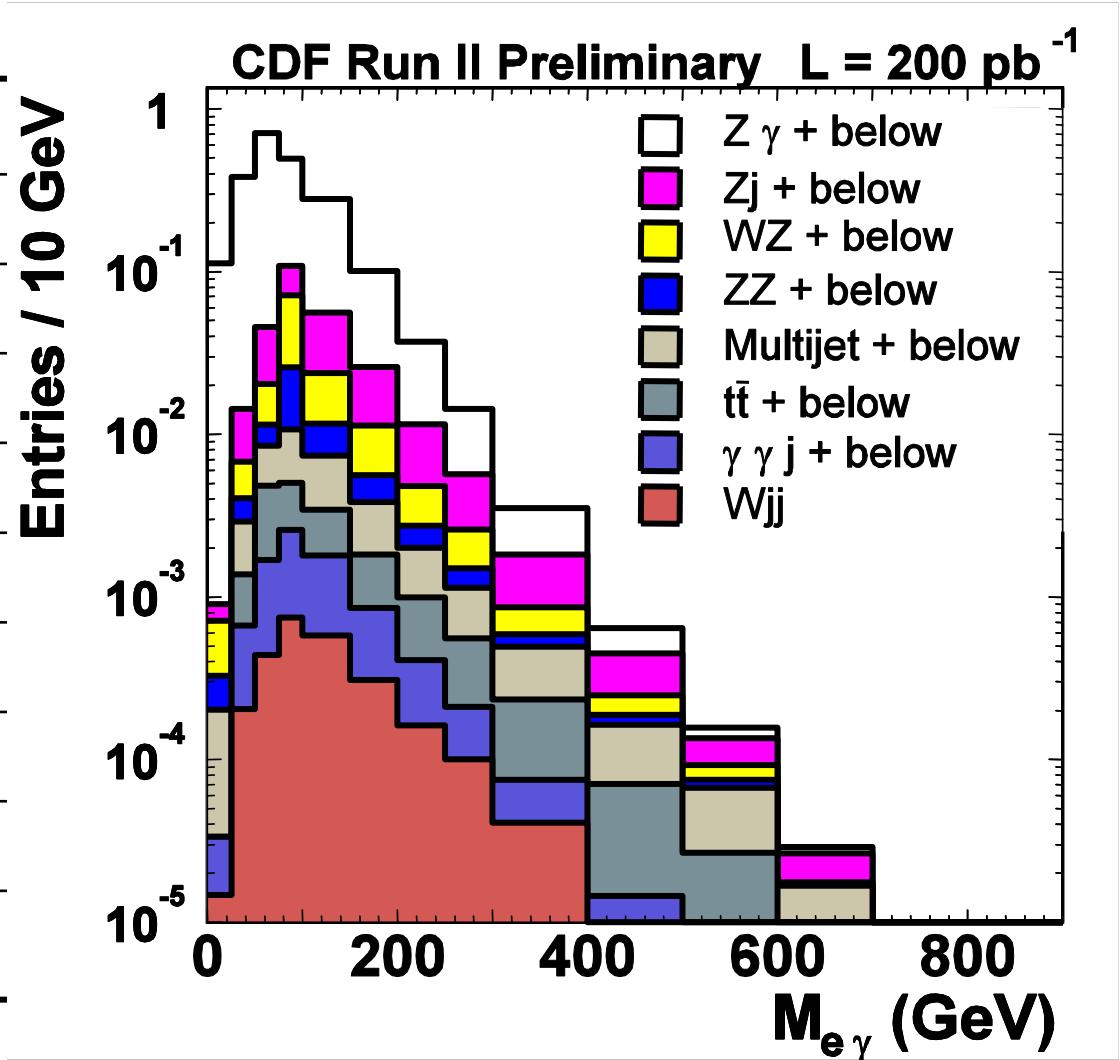
► $M_{e\gamma}$ and $M_{ee\gamma}$ Background Distributions:

- $M_{e\gamma}$ is the search channel (all combinations of $e\gamma$ are used)
- $M_{ee\gamma}$ for the case that new physics is the results of a 3 body decay rather than the models chosen in this search



$M_{e\gamma}$ Background Distribution

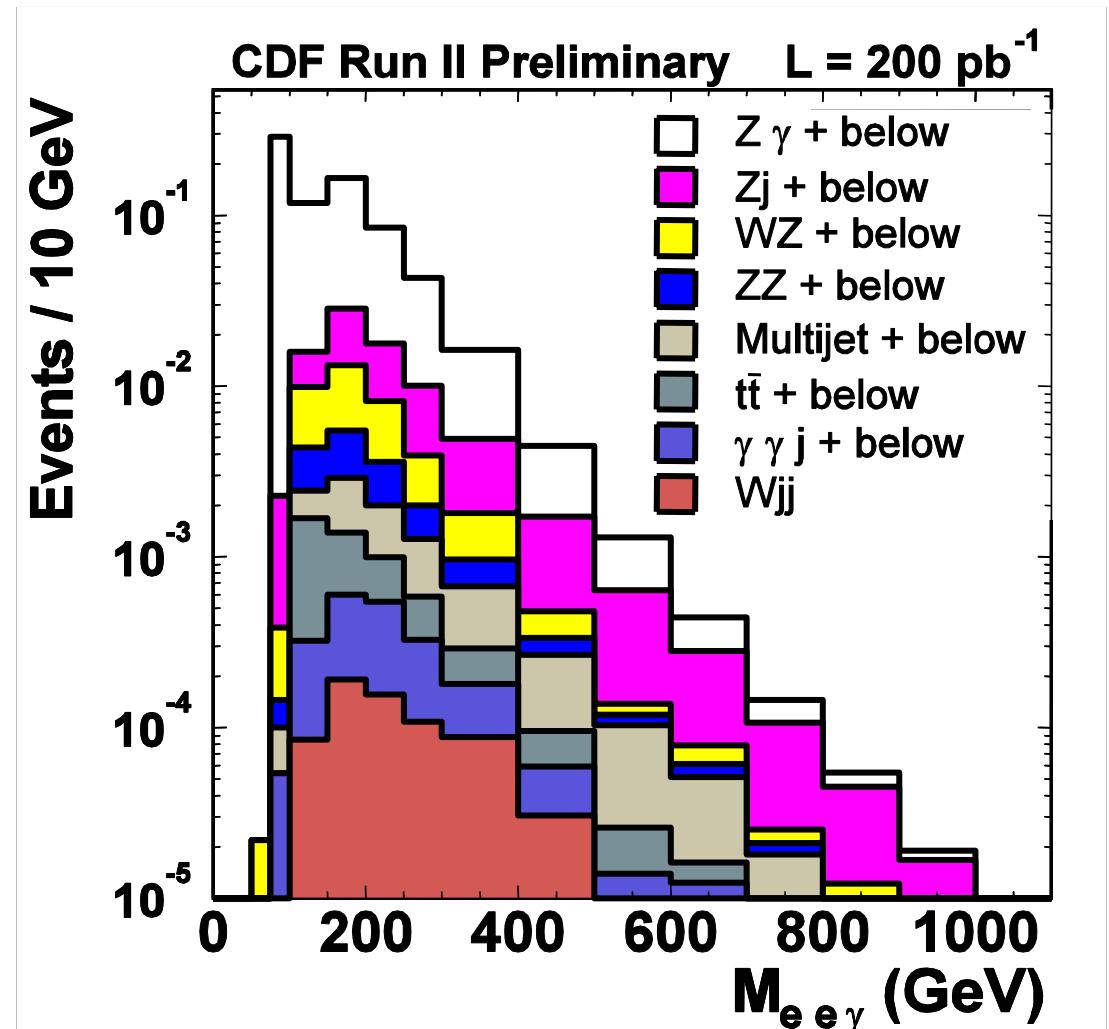
Source	$e\gamma$ Entries
$Z(\rightarrow ee)\gamma$	5.52 ± 0.53
$Z(\rightarrow ee) + \text{jet}$	$0.48^{+0.47}_{-0.12}$
$W(\rightarrow e\nu)Z(\rightarrow ee)$	0.25 ± 0.03
$Z(\rightarrow ee)Z(\rightarrow ee)$	0.08 ± 0.01
Multi-jet	$0.07^{+0.09}_{-0.03}$
$t\bar{t}$	0.03 ± 0.01
$\gamma\gamma + \text{jet}$	$0.022^{+0.024}_{-0.004}$
$W(\rightarrow e\nu) + \text{jet}$	$0.010^{+0.015}_{-0.004}$
Total	$6.47^{+0.83}_{-0.58}$





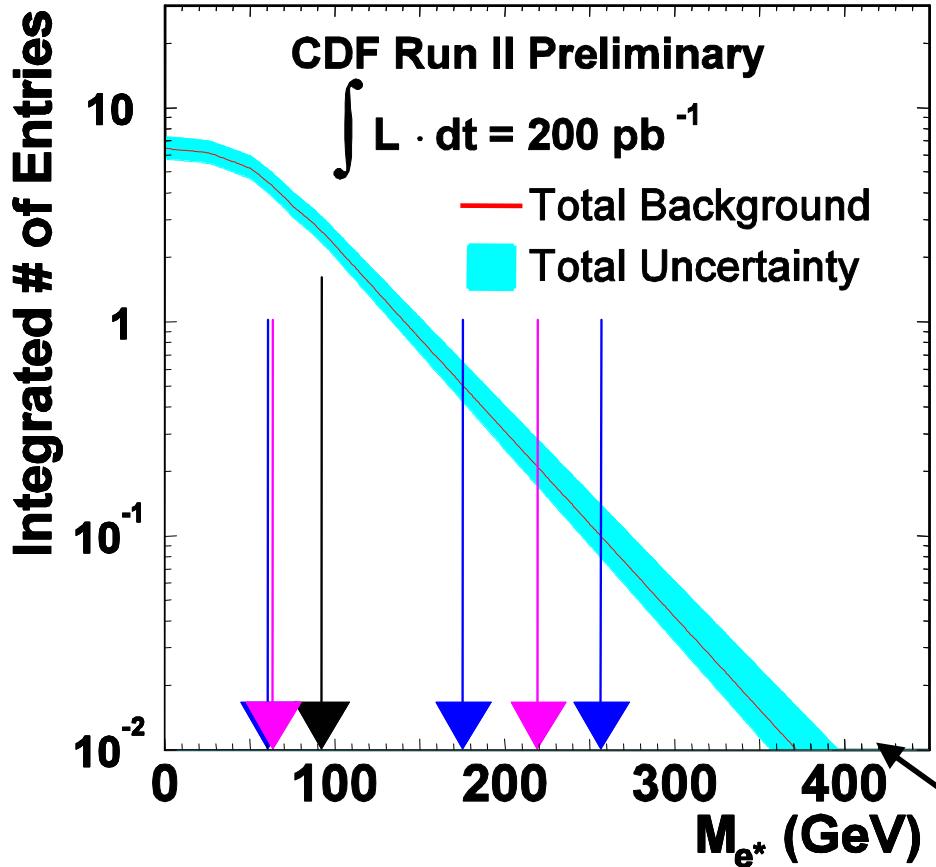
$M_{ee\gamma}$ Background Distribution

Source	Events
$Z(\rightarrow ee)\gamma$	2.56 ± 0.24
$Z(\rightarrow ee) + \text{jet}$	$0.24^{+0.24}_{-0.07}$
$W(\rightarrow e\nu)Z(\rightarrow ee)$	0.11 ± 0.01
$Z(\rightarrow ee)Z(\rightarrow ee)$	0.038 ± 0.004
Multi-jet	$0.03^{+0.03}_{-0.01}$
$t\bar{t}$	0.015 ± 0.005
$\gamma\gamma + \text{jet}$	$0.008^{+0.005}_{-0.003}$
$W(\rightarrow e\nu) + \text{jet}$	$0.004^{+0.005}_{-0.002}$
Total	$3.01^{+0.39}_{-0.28}$





M_{e^*} Integrated Background Distribution

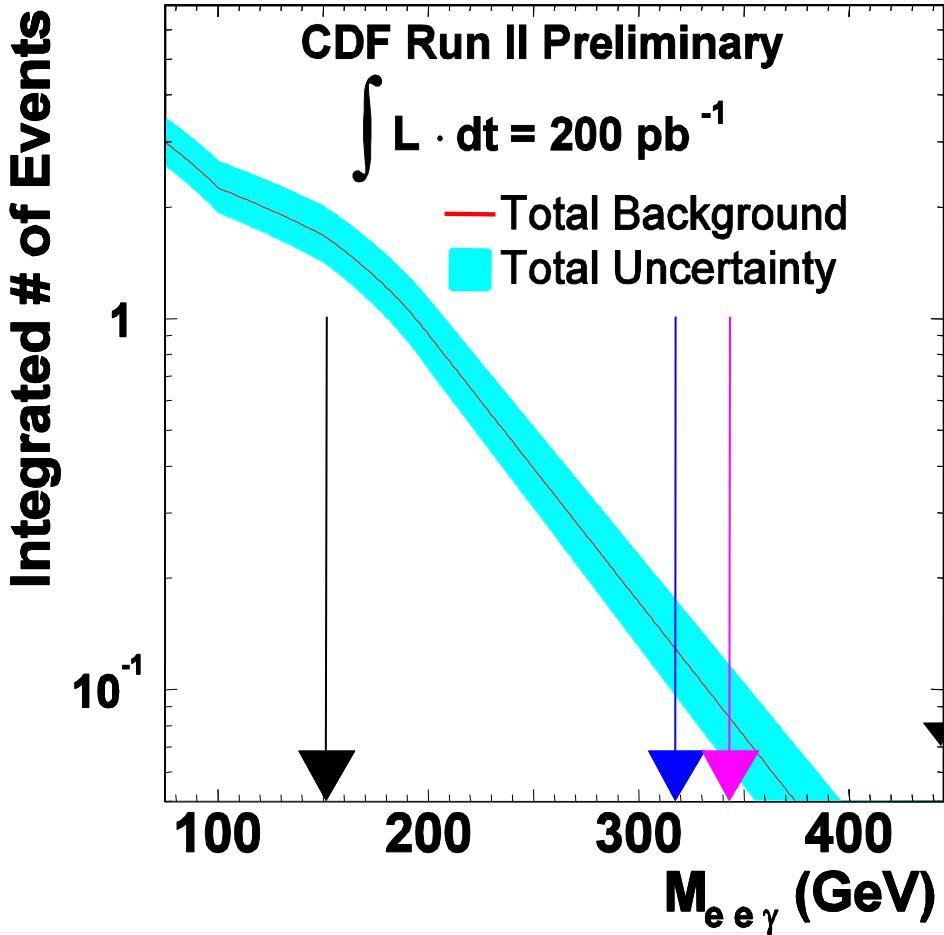


$M_{e\gamma}$ (GeV)	Background	N_{obs}
>0	$6.5^{+0.9}_{-0.6}$	7
>50	$5.2^{+0.8}_{-0.6}$	7
>100	$2.2^{+0.4}_{-0.3}$	3
>150	$0.8^{+0.2}_{-0.1}$	3
>200	$0.31^{+0.10}_{-0.05}$	2
>250	$0.11^{+0.04}_{-0.02}$	1
>300	$0.04^{+0.02}_{-0.01}$	0

- Blue for Run=144674 Event=4143240
- Black for Run=147806 Event=1167222
- Pink for Run=167866 Event=443088



$M_{ee\gamma}$ Integrated Background Distribution

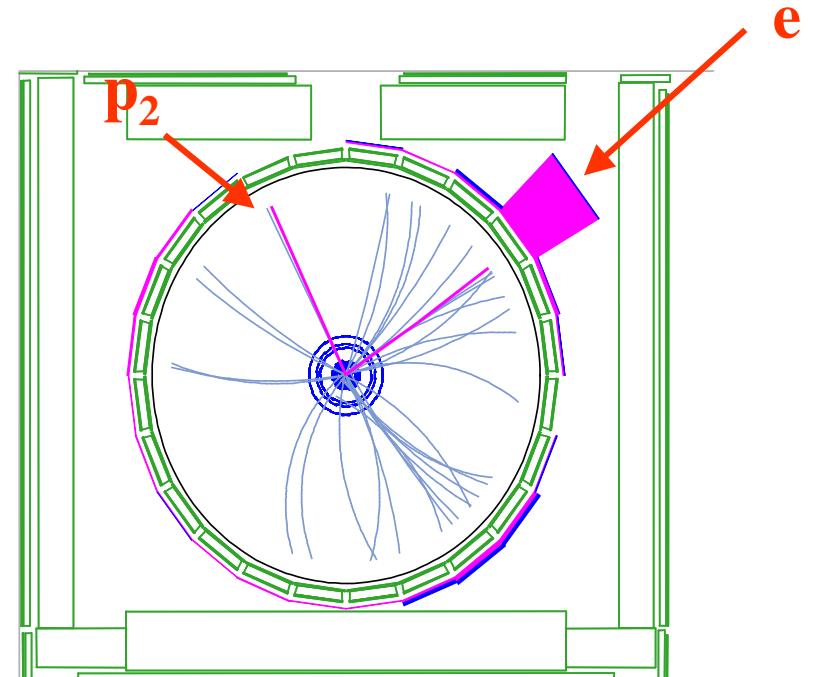
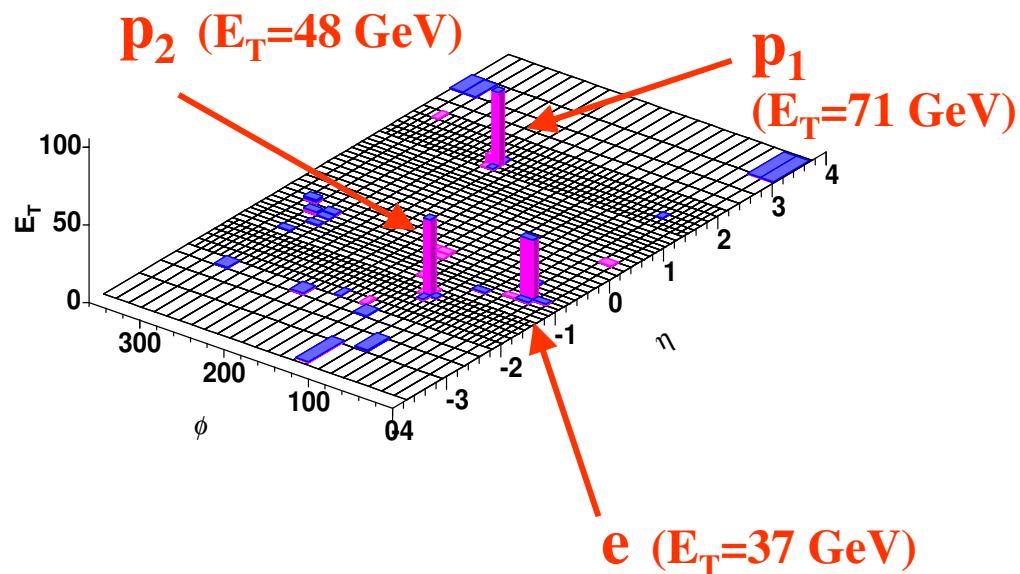


$M_{ee\gamma} (\text{GeV})$	Background	N_{obs}
>0	$3.0^{+0.4}_{-0.3}$	3
>100	$2.2^{+0.4}_{-0.3}$	3
>150	1.7 ± 0.3	3
>200	0.9 ± 0.2	2
>250	0.4 ± 0.1	2
>300	$0.17^{+0.06}_{-0.04}$	2
>350	$0.07^{+0.03}_{-0.02}$	0

- Blue for Run=144674 Event=4143240
- Black for Run=147806 Event=1167222
- Pink for Run=167866 Event=443088

Run=144673 Event=4143240

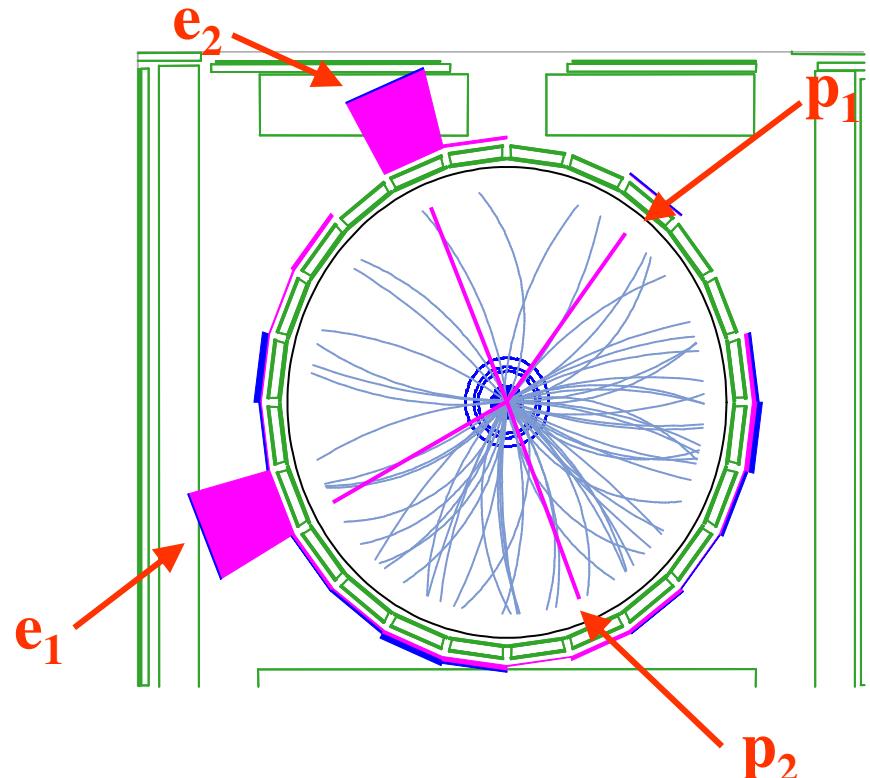
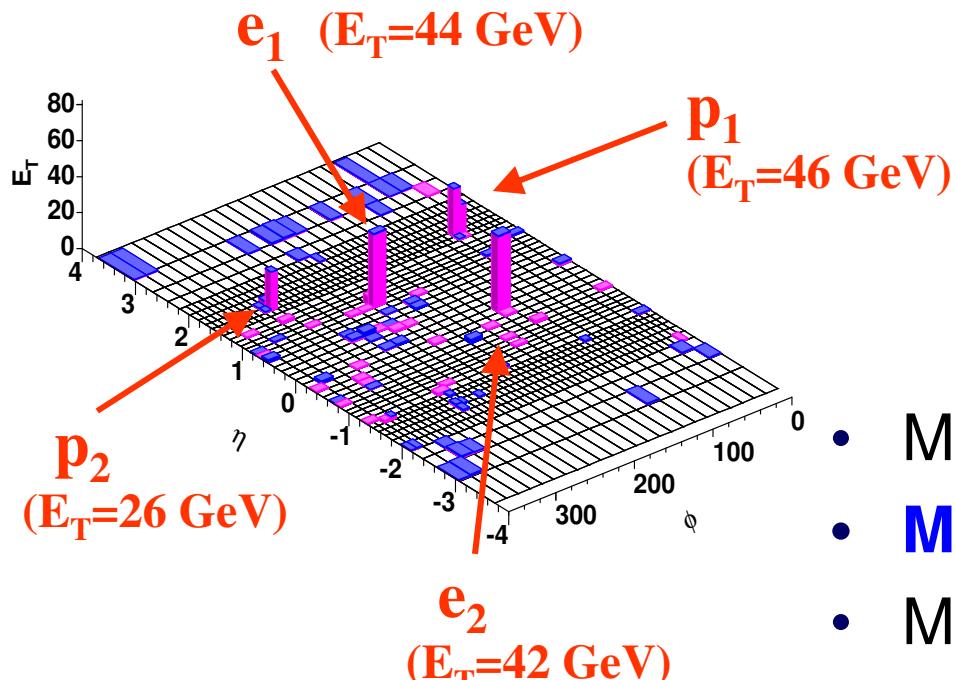
- One central electron (e), two plug EM objects (p_1 and p_2)



- $M_{ep_1} = 176$ GeV
- $M_{ep_2} = 61$ GeV
- $M_{p_1 p_2} = 257$ GeV
- $M_{e p_1 p_2} = 318$ GeV

Run=147806 Event=1167222

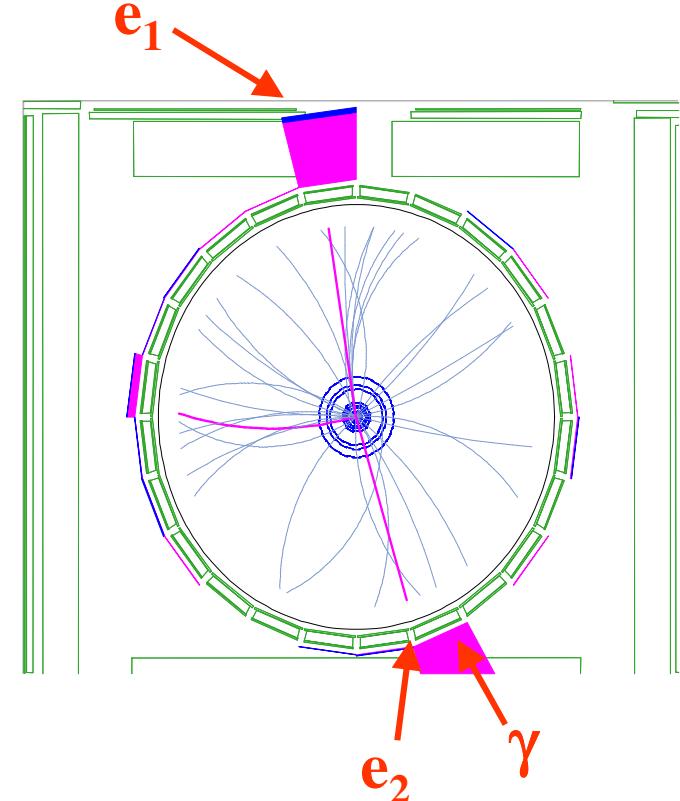
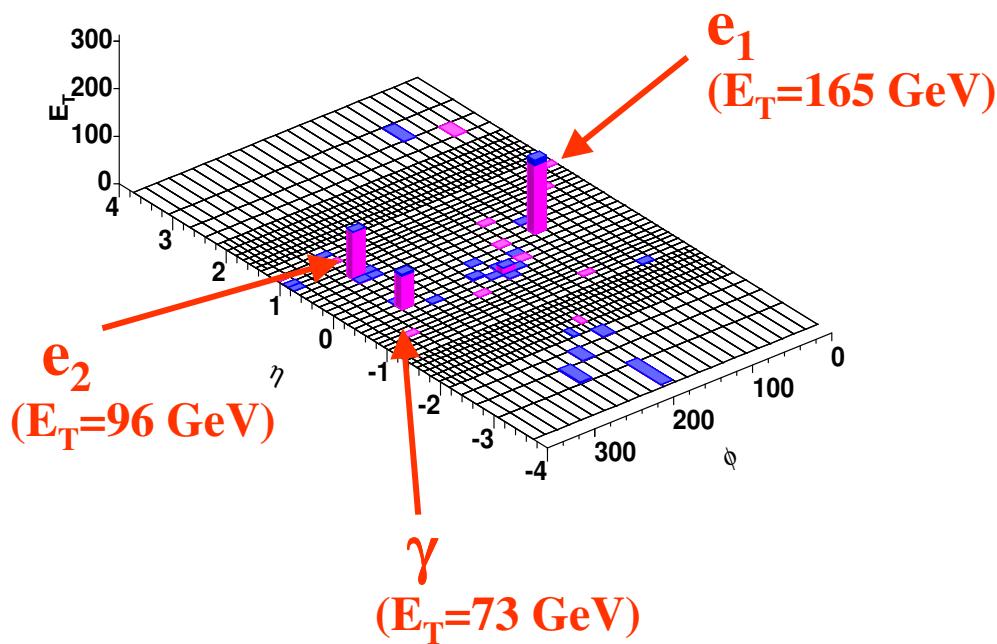
- ▶ 2 Central Electrons (e_1 and e_2),
2 Plug EM Objects (p_1 and p_2)
- ▶ ZZ Candidate Event??



- $M_{e_1 e_2} = 78$ GeV
- $M_{e_1 p_1} = 92$ GeV
- $M_{e_2 p_1} = 91$ GeV
- $M_{e_1 e_2 p_1} = 152$ GeV
- $M_{e_1 e_2 p_2} = 91$ GeV
- $M_{e_1 e_1 p_1 p_2} = 194$ GeV

Run=167866 Event=443088

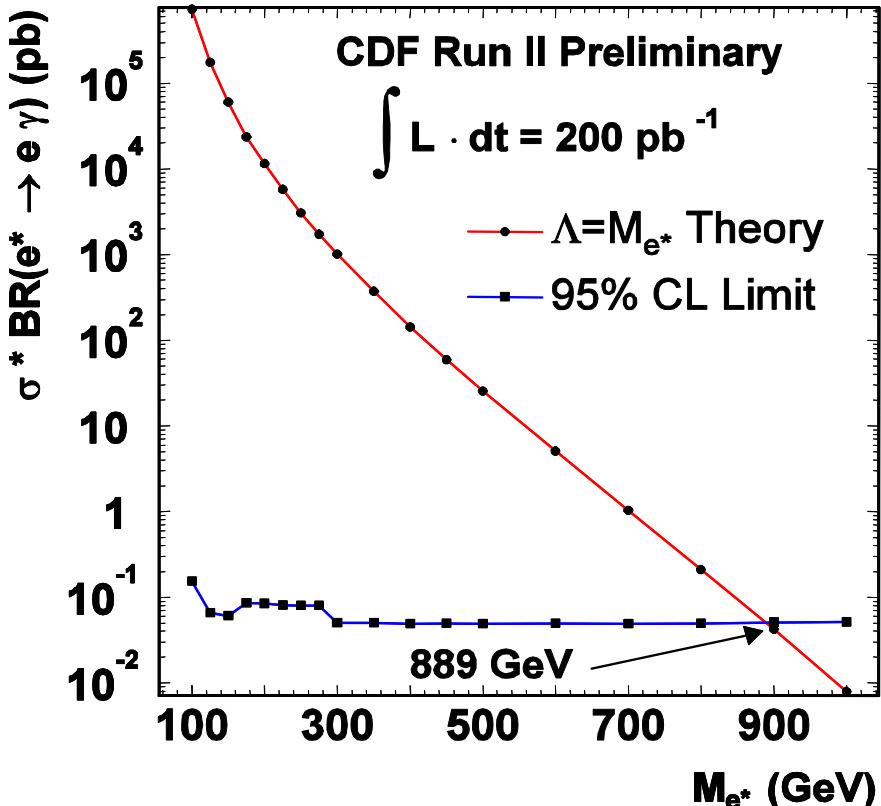
- ▶ 2 Central Electrons (e_1 and e_2),
1 Central Photon (γ)



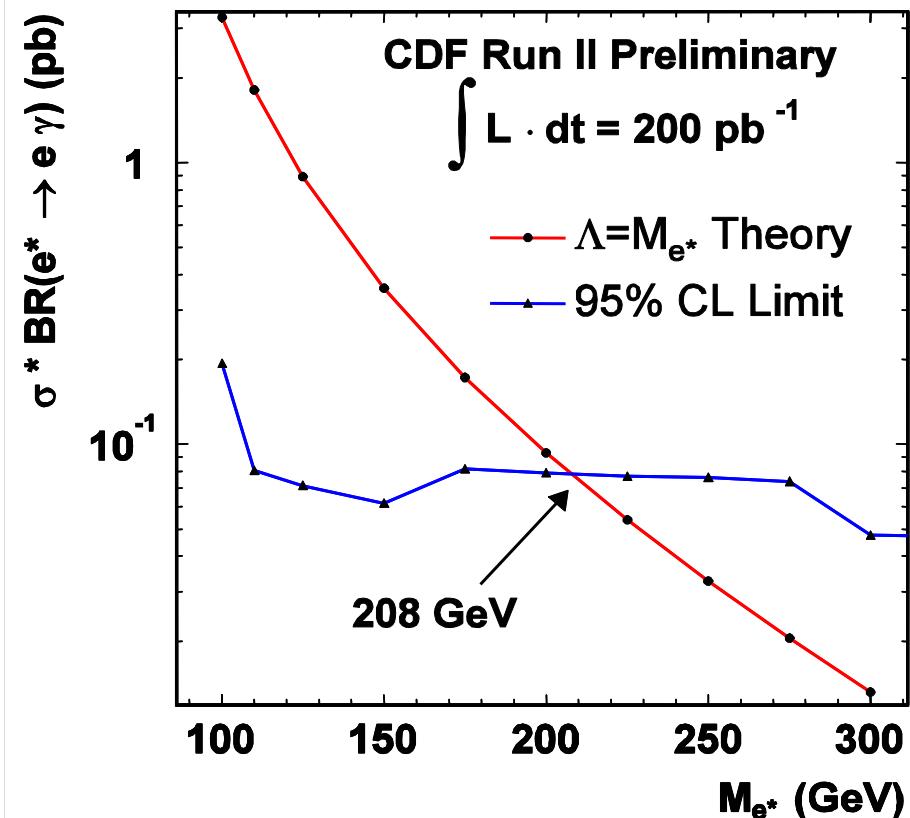
- $M_{e_1 e_2} = 256$ GeV
- $M_{e_1 \gamma} = 220$ GeV
- $M_{e_2 \gamma} = 64$ GeV
- $M_{e_1 e_2 \gamma} = 344$ GeV

Experimental Limits for $M_{e^*} = \Lambda$

- ▶ Using a Bayesian approach, we obtain upper limits on the experimental cross-section and lower limits on the e^* mass



- Contact Interaction Model

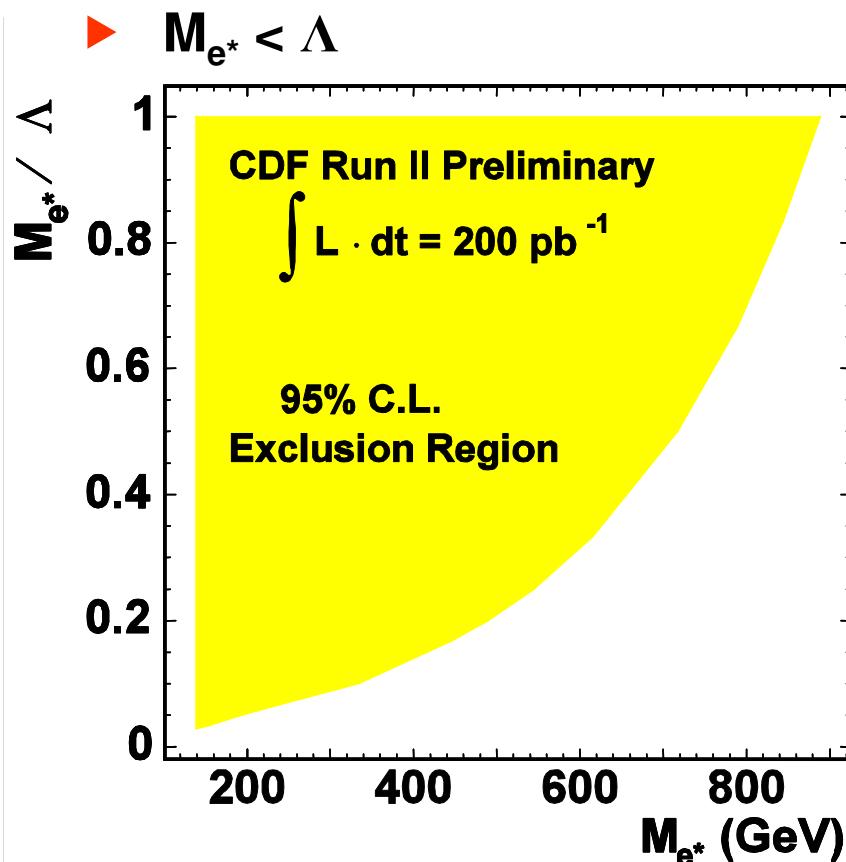


- Gauge Mediated Model



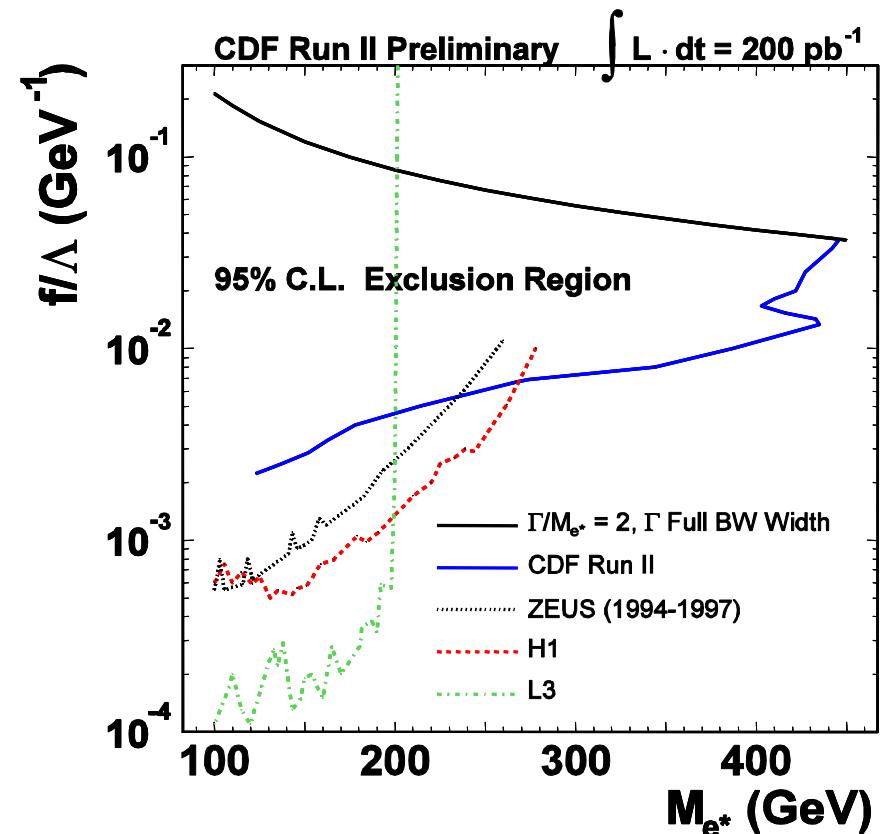
2-D Experiment Limits

- Contact Interaction Model depends on M_{e^*} and Λ



- No published limits

- Gauge mediated model depends on M_{e^*} and f / Λ



- L3: hep-ex/0306016, Zeus: hep-ex/0109018, H1: hep-ex/0207038



Summary

- ▶ Three high mass $e\bar{e}\gamma$ candidates were found in 200 pb^{-1} , while the total background prediction was ~ 3 events
 - One event could be a ZZ candidate
 - Other two events have interesting characteristics
- ▶ For $M_{e^*} = \Lambda$:
 - Contact Interaction Model, $M_{e^*} > 889 \text{ GeV}$
 - Gauge Mediated Model, $M_{e^*} > 208 \text{ GeV}$
- ▶ Established 2-D exclusion region in $M_{e^*} / \Lambda - M_{e^*}$ plane for contact interaction model
- ▶ CDF results extend sensitivity in $f / \Lambda - M_{e^*}$ plane for $M_{e^*} > 280 \text{ GeV}$ for gauge mediated model
- ▶ Eager to look at new data and extend these searches